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Ubiquitous e-learning System for Dynamic Mini-courseware Assembling and Delivering to Mobile Terminals

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Abstract—**From 2000, mobile Learning (m-Learning) and ubiquitous Learning (u-Learning) has been the hottest research topic in e-learning, and now, integrating ubiquitous learning into mainstream of education and train has been the direction in the area, which demand new generational e-learning system. The paper introduces our research efforts in this direction. Based on the key concepts, such as ubiquitous learning object, mini-courseware, a new generational ubiquitous e-learning system is designed, which can be used for new requirements in m-Learning and u-Learning environments. In the system, learning resource related to a course is encapsulated into different ubiquitous learning objects, and mini-courseware can be assembled dynamically with learning resource extracted from these ubiquitous learning objects, accordingly, a mini-courseware player is designed for the situation. Based on these work, a resource-based ubiquitous e-Learning system is designed considering pedagogical requirements under m-Learning and u-Learning environment.**

Keywords-mobile learning; ubiquitous learning; mini-courseware

I. BACKGROUDN

With fast development of wireless communication technologies and embedded mobile devices, there have been many researches work on m-Learning and u-Learning. From the perspective of application domains, the technology has been used in k-12 (e.g. the research of University of Michigan on handheld used in k-12[1]), in university (e.g. Lancaster University's project[1]) or in career development area (e.g. Medical Education project of University of Oslo[2]). There are also some research works carried out in open universities [3]. From application modes, there are applications in class learning (e.g. x-Task research in Finland[4] and in outdoor learning (e.g. BWL in Taiwan[5]).

Accordingly, new generational e-Learning system has been the key for further development of m-Learning. Now, there are three kinds of mobile system, the first one is SMS-based m-Learning system. A research group of Kingston LTRG from UK has developed a SMS-based e-Learning system, which can be used for teaching management, and lots of information can be delivered to learners by the system, such as some kind of learning activities, exam timetable, score of tests, etc. Another example of this kind m-Learning system is a project from Africa, in which courses of Education Master, Advanced Educational certificate of Pretoria University are delivered to rural area. The second one is based on web browser, for example, Poodle is a system for m-Learning management [6], with which learning resource for mobile phone can be developed expediently. In Poodle, the service of online test, discussion forum, flash player are provided. The KNOWMOBILE project from medicine of Oslo university is also a web based m-learning system[7], and it can be used for professional development for student of medicine specialty. With the system, students can query materials or solve problem with PDA or WAP-enabled mobile phone. The third one is client-server based m-Learning system, such as the project of "Form E-Learning to M-Learning", in the project, the open university of NKI from Norway develop a series of courseware suitable for mobile devices, such as PDA, Smart phone, etc., and accordingly, a client for playing courseware is also developed [8].

From these research efforts, it is clear that there are inherence requirements in m-Learning and u-Learning environment. First, the features of context, informal, mini-learning activities have been the keys points of m-Learning and u-Learning compare to traditional learning technology. Second, in m-Learning and u-Learning environment, various mobile devices are used for learning activities, which demand new e-Leaning system for muti-devices access. Today, the research on e-Learning system supporting multi-device access has been the key of the research field, and there have some research efforts in this direction. In literature[9], mobile learning object is proposed, and accordingly, mobile learning objects should be designed, developed and used taking into consideration the advantages of mobile devices and the learning approaches that support m-Learning environments. In literature [10], learning objects represent a means of rendering learning content interoperable on a wide range of devices in different formats using XML for usability on small and large screens. Metadata is the key to the use of learning objects, and in this paper, pedagogical and other types of metadata are important in the implementation of learning systems for use by mobile devices. In literature [11], a architecture is defined for

learning object repository, which is independent and able to be accessed from a multiple bunch of devices, independently of its individual and special features. In literature [12], the issues of transferring the current PC based Sharable Content Object Reference Model (SCORM) to Pocket PC based is discussed for creating ubiquitous learning using mobile devices. Learning resource in Pocket SCORM is able to operate, even when the mobile device is offline. The literature [13] describe the implementation of adaptive pocket SCORM reader, and the proposed pocket SCORM reader is able to load SCORM compatible courseware. In literature[14], a u-learning system, called Hard SCORM, is introduced, and the system allows learners to read SCORM-compliant textbooks using multimodal multimedia devices, and the system has also been used by an airline company for online security checking and a high school for online m-Learning. Among them, Learning Object is the most promising technology for the requirement. On the other hand, the adaptive feature of m-Learning / u-Learning system has also been the important research topic in this area, for example, In literature[15], adaptive feature of m-learning system is realized with multi-agent technology.

Our research work focuses on new generational e-learning system, in which the technology of Learning Object is used and further designed for m-Learning/u-Learning system. In the system, learning resource is imported into Ubiquitous Learning Object, and also a programmable facility is provided for dynamic learning resource extracting and mini-courseware assembling. The paper introduces our research work in this direction. In section 2, the key concepts of the system are introduced, which is foundation for developing new generational e-learning system. In section 3, the architecture of this new e-Learning system is introduced, which include the module for Ubiquitous Learning Object creating, publishing, managing, and the module for adaptive engine. In section 4, a mini-courseware player suitable for this new generational e-Learning system is presented, and learning model supported by the player is also described. In section 4, further research of our work is introduced.

II. THE KEY CONCEPTS: UBIQUITOUS LEARNING OBJECT AND MINI-COURSEWARE

A. Ubiquitous learning objects and the mechanism for its realization

In our research, the concept of Ubiquitous Learning Object (ULO) is proposed （refer to figure 1, figure 2, figure 3). Different to existing learning object, ULO include two parts, one is metadata model, and the other is behavior model. The elements and their features in the metadata model of ULO are optimized from existing specification, such as LOM, SCORM, etc., and the proposed metadata model is more appropriate for terminals in u-Learning environment. For realization of learning object behavior, a programmable facilities should be provided, which can be used for modifying and expanding behaviors on ULOs. The

mechanism is used for satisfy varied requirements in ubiquitous learning environments. The programmable facility should be realized with web services technologies. The following is brief introduction of the two model related to ULO concept.

- Data model. The elements in metadata schema are classified into two levels (refer to figure 1), the upper level is related to overiew features of a ubiquitous learning objects, and the lower level is used to described medias binded to a special ULO. Details explain of these elements can refer to literature [18].
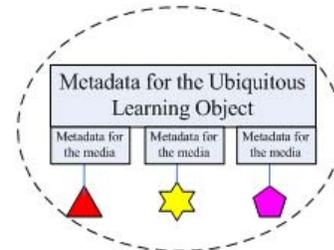

Figure 1. Proposed metadata model for ULO

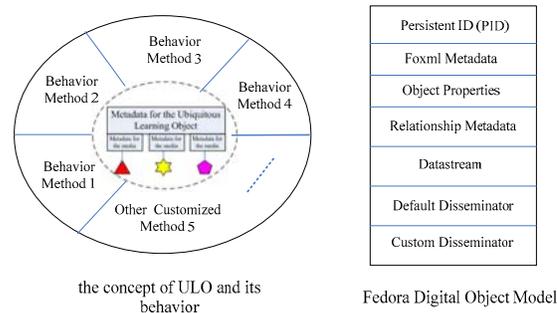the concept of ULO and its behavior   Fedora Digital Object Model

Figure 2. ULO and mechanism for realization of its behavior

- Behavior model. The model is provided for every ULO, and it is more important for understanding the difference between ULO and learning object in traditional e-Learning environment. The behavioral features of a ULO should have following characteristics: Firstly, behaviors of a ULO can be customized according to carried media in the ULO. Because medias in a ULO are organized based on knowledge points of a course, and they usually be represented in different media formats. Secondly, due to varied networking status, different physical characteristics of terminals, and various preferences of users in ubiquitous learning environment, the capability of extracting/delivering media adaptively from a ULO is strongly needed. With these kinds of behavioral capability requirements in ULOs, web services technologies are selected in our research work, because it can supports modifying behaviors of a ULO while the system is running. In our research, the runtime environment for extensible and configurable ULO behavior through web service is realized based on Fedora[16].

Brief introduction of the programmable facility with web services technologies is described here. The Fedora service framework facilitates the integration of web services

on ULO, and it takes a service-oriented architecture approach to adding new functionality around Fedora data object repository, allowing new services to be built around the core repository as stand-alone web applications that run independently of Fedora. The programmable facility for flexible and extensible functions in the prototype system are described in figure 3, which is realized with web services technologies and inherited from Fedora. Hence, the behaviors on a ULO can be extended and reconfigured with web service, which is implemented with two kinds of Fedora data object, and they are Behavior Definition Object and Behavior Mechanism Object, and these two kinds of objects are special data objects in Fedora.
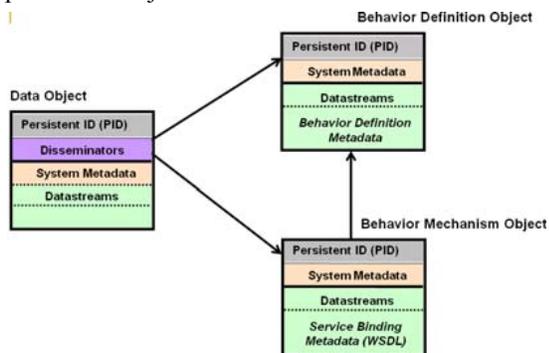

Figure 3 Mechanism for behavior extension of ULO in the system

With the flexible and extensible programmable facility by web services technologies, the behaviors on a ULO can be extended and reconfigured in flexible way, which is important for the realization of adaptive features of m-Learning and u-Learning systems. All these services (new added ULO behaviors) can be integrated with Fedora framework easily, and they can be integrated into the framework in two kind methods: Firstly, Dynamic Content Delivery: any special web service can be associated with any data streams in a ULO object. Accordingly, dynamic content can be delivered from the ULO, which is output of a web service for processing data in the object. Secondly, Management and Access APIs, ULO object repository runs as a service within a web server, and all of its functionality and features of ULO object model can be accessed through well-defined REST and SOAP interfaces.

B. The concept of mini-courseware

In m-Learning scenarios, the learning activities with mobile devices should be context-based and short-time based, therefore, the learning resource on mobile terminals should be mini, which should have the follow features. First, mini learning resource section, and the section can be learned within 10~15 minutes. Second, the functions of replaying, reloading and relocating learning resource in client should be supported. Accordingly, these features should be realized within the process of ubiquitous learning object creating,

delivering and replaying, at the same time, the process should embed capabilities for realization of adaptive features.

In this way, the functions from Learning Object technologies, adaptive capability produced from behaviors on ULO can be integrated into an integrated facility, and the programmable facility is created for m-Learning and u-Learning environment with web services technologies for abstract operation definition, implementation, and dynamic binding.

III. THE ARCHITECTURE OF PROPOSED UBIQUITOUS E-LEARNING SYSTEM

Based on the key concepts and features required in m-Learning and u-Learning environment, a suitable system architecture should be designed. The main functions of the architecture should support learning resource extracting from learning objects and assembling them into mini-courseware, which can be replayed on mobile devices. The architecture of the system is designed according to our research activities, which mainly includes two parts (refer to figure 4).

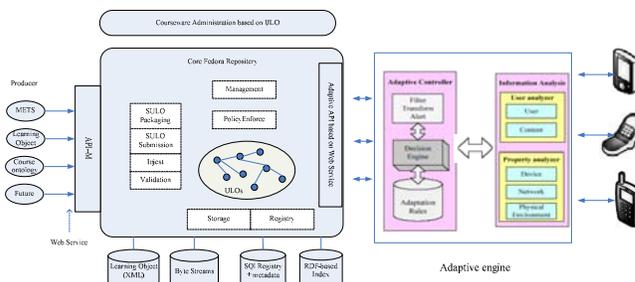### A. The module for creating and managing ULO

Figure 4. The architecture of ubiquitous e-learning system

In this module, tools and facilities for ubiquitous learning object creating, publishing, and managing have been designed. The creating and managing of ULO is the foundation of the system, which is mainly realized through SULOMS (Semantic-oriented Ubiquitous Learning Object Management System), and SULOMS is extended from Fedora system. Initially, Fedora uses Dublin Core as metadata schema, and it has been expanded by our research team to the proposed metadata model aforementioned (refer to figure 4). Now, the integrated functions for ULO object creating, ingesting, storing and managing have been realized, at the same time, the operations on a ULO can be reconfigured and extended according to adaptive features required by different m-Learning contexts. Now, main sub-modules of this module include course structure management module, ULO module, etc. The course structure management module can be used to provide convenient access for teachers or resources providers when they build their own course structure and create ULOs under the structure. ULO module is provided to enable resources providers (such as teachers, curriculum experts, et al.) to package learning

resources in the way of ULO. The process for ubiquitous learning object creation can be found in the paper[17].

B. The desgn of adaptive engine

The feature of adaptation of m-Learning and u-Learning system is most important today, and there are many characteristics for adaptation. Now, in our research, we consider adaptation about four dimensions: learner, device, connectedness and learning environment. Learner dimension contains learner's preference. Device dimension contains the type of terminal device, disposal capacity, screen size, memory size and supported multimedia formats etc. Environment dimension contains the environment of learning activity happened in such as time, place, noise etc. Connectedness dimension mainly considers the condition of network such as available bandwidth, delay and error ratio. With these considerations, the adaptive engine consists of two modules: information analysis module and adaptive controller module (refer to figure 4).

- Information analysis module. The module including user analyzer and property analyzer, which is used to analyze learner's basic information. User analysis part is used to analyze the content of user requirements and user preferences such as preferences to audio, video or text. Property analysis part is used to analyze the features about mobile devices used in learning (i.e. types, disposal capacity, screen size, memory size, and supported multimedia formats etc.), network condition (i.e. available bandwidth, delay, and error rate, etc.) and environmental information of learning activity happened (i.e. time, noise, etc.). The information that this analyzer obtained will be sent to adaptive controller module as necessary parameters for the realization of system's adaptation.

- Adaptive controller module. In the process of adaptation, adaptive controller module chooses learning resources for users through suitable behavior dynamic binded through web service to meet specific performance and user preferences according to parameters obtained by information analysis module. This module consists of adaptive decision rules, learning resource adaptive conversion module and decision engine. **Firstly**, Adaptive decision rules. A set of rules were developed to determine what kind of resources can be sent to user in certain circumstance. **Secondly**, Decision engine. Decision engine is the core of the adaptive engine system which assembles resources dynamically. In the process of assembling, it will refer to adaptive decision rules. The decision engine will match parameters obtained from information analysis with adaptive rules to decide which resources should be sent and whether the resources should be converted. The decision process can be divided into three steps. ***Firstly***, format matching. After picking up desired learning objects, the system matches original formats of resource with client supported media formats, and decides whether to convert resources on the basis of transformation rules in adaptive decision rules. ***Secondly***, balancing the parameters. The resources, which will be downloaded into client, will be balanced with collected information, such as user preference,

device's property information, or downloading time according to computation. It aims to make the time and resources can be acceptable for user as a whole. ***Thirdly***, identify priority of learning resource in different ULOs. The system chooses the final available resources. For example, the transmission time is prior than user preferences, the text is prior than image and the image is prior than audio. **Thirdly**, adaptive learning resources conversion module. With the command from adaptive engine, this module filters, chooses and converts resources. Finally, suitable learning resources are selected and delivered to user's mobile devices.

The whole process of adaptive system is shown in figure 5. After establishing connection between client and server, network monitoring module checks network condition while client property module gets learner's preference, device property etc, then, the system finds out whether existing resources in cache table fit to these parameters. If there are available resources, send their list to the client. Otherwise, the adaptive engine will filter, convert and select resources from Fedora-extended SULOMS' learning object repository according to these parameters, and finally learning resources are generate and delivered to client. Generally speaking, there are great deals of knowledge points and contents in a whole course. However, the capacity of mobile device, such as storage capacity, screen size, supported media formats and so on, is limited. Therefore, the whole course learning resources will be much simpler in order to assure learners could get integrated content of a course (called mini-courseware, and mini-courseware is compose of learning resources representing knowledge points).

From the viewpoint of client, the adaptive engine analyzes the requirement is for whole learning course (mini-courseware) firstly. If it is for whole course learning, the system will dispose resources according to the parameters of device, and then select them by learner's preferences. In this way, the content of every knowledge points in a mini-courseware is sent to learner. However, in this model, it is hard to assure that every resource sent to learner is appropriate for learners. After the whole course learning, the learner may want to learn some knowledge points in depth, then, he could choose In-depth learning model (introduced in paragraph 4). In this mode, adaptive engine will give learner the best resources which are totally fitting to learner's preferences to satisfy the learner's requirement for detailed study. For In-depth learning, the system will filter resources according to learner's preferences first, and then select or convert them according to supported formats of the device, the available memory space and network condition.

IV.   THE REALIZATION OF A MINI-COURSEWARE PLAYER ON MOBILE DEVICES

Based on the system architecture we mentioned above, we develop a mini-courseware player (client), with the player, learners can search, view, and download the whole course (mini-courseware) or part of it (knowledge points) to study offline. In our research, four terminals are selected for experiment, which are N93i Nokia smart phone, Sony Ericsson p990i smart phone, Dopod D9000 PDA and low-end Nokia 5200 handset.

A. Two learning models for m-Learning

Considering the learning requirements in m-Learning and u-Learning environments, different learning models are designed for the player. Now, there are two kinds of learning models provided by the client: simple learning model and in-depth learning model. **Simple learning model**: when a learner browsing the course list offered by server, he may chooses the whole course (mini-courseware) to download, we call this a simple learning model, because there is a whole process for creating a mini-courseware adaptively. Considering the learner's requirement as well as the limitation of mobile device in storage and computing power, the resources sent to learner's mobile device may be simple, such as only text. **In-depth learning model**: If a learner chooses a section or content for a set of knowledge points to download, we call this situation as in-depth learning, because the learning resource delivered to client in simple learning model is simple and light, and in in-depth learning model, resources for a knowledge point can be represented by heavy media, such as medias in video or flash, etc.
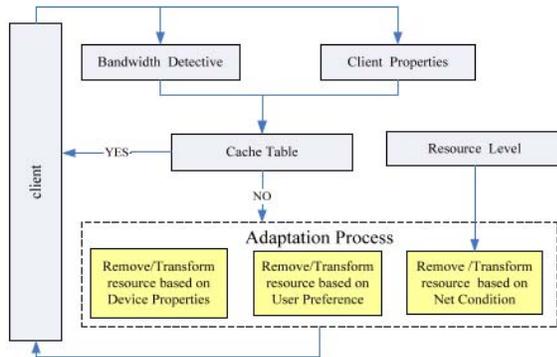

Figure 5. the process of adaptation

B. Manifest of mini-courseware structure

With variation capabilities of storage capability, display size, etc, mini-courseware structure (called manifest), is designed, which is used as carrier of mini-courseware. Manifest of a mini-courseware is delivered to mobile devices preferentially, which is used to present the structure of whole mini-courseware. In some situation, none of item in the structure has special URL, indicate that the item is pending to special resource, because when the server transmits this manifest, the URLs of resources have not been decided. Only after the client makes sure which part is learner's requirement, the adaptive module decides the URLs and sends them to client. Based on this manifest, client parses course structure and generates relevant learning "activity".

C. Main functions of mini-courseware player

The mini-courseware player provides following functions.
- Online learning module: The online learning module mainly meets the needs of learners' mini-courseware-based or knowledge points-based searching, download and display of relevant resources, tracing of the learning process. The online learning search offers two kinds of searching methods, namely mini-courseware-based search and knowledge point-based search. When learners conduct course-based learning, they select mini-course-based search. Otherwise, they select knowledge-point-based search. The search for online learning is based on key words. Learners request resources downloading by selecting the name of mini-courseware or knowledge points. The server provides resources most suitable for the environment according to the names of mini-coursewares or knowledge points requested by the learners according to adaptive process. When the resources have been downloaded, the client displays the structure of the mini-courseware according to their tree-like structure. In light of size of the terminal screen, each screen shows only those nodes at the same hierarchy in the tree-like structure, and learners get to the next node by clicking the corresponding nodes. During the learning process, the player will record learners' learning conditions, and mark each chapter with the three kind signs of "having been learnt", "being learnt" and "not having been learnt" according to real learning process. When all the sub-nodes of a particular node have been studied, the node will be marked as "having been studied"; and when none of the sub-nodes of a particular node have been studied, the node will be marked as "not having been studied". When learners withdraw from the current learning, the structure of the mini-courseware, the learning condition of every node and the table of resources will be saved on the mobile devices. Anyway, when a learner find mini-coursewares that the learner wants to study, the learner can download the whole mini-courseware or a part of it. If the learner chooses to simple-learning model we mentioned above, simple resources will be transmitted, If in-depth learning model, the server will transmit the suitable resources through adaptive engine, which is processed as learner preference and learning habits.

- Offline learning module. After learner downloads mini-coursewares, learner can study the course offline without connection to server. When studying courses offline, the learner can also view the structure of courses and learn based on it. The client software will search the mobile terminal for mini-coursewares already existing, and read the structure of mini-courseware. The node of course structure will be marked in different colors and font types according to the learning condition in order to support learners' offline learning. In the process of offline learning, the client will also record the whole learning process as it does in online learning.

- Mini-courseware managing module: In course managing, the client will search for mini-courses already existing at the mobile devices, and display them to learners as a table consisting of course names and the sizes of corresponding resources. Learners manage existing course by selecting or deleting the name of mini-courseware chosen.

- Environment property module: Environmental attributes include terminal screen size, storage capacity, current network speed, user preferences, file formats it supports, etc.. When users ask for downloading mini-courseware, the environmental attributes will be conveyed to server. Then, adaptive engine will work according to the

process aforementioned. Since each commencement of the software is at different location, for example, the current speed of network attributes should be tested at the same time. When users ask for resources, the client will prompt them to choose learner's preference settings.

In figure 6, the realized function of mini-courseware query, the structure of mini-courseware and the display of mini-courseware is displayed.

V. FURTHER RESEARCH WORK

Now, the aforementioned architecture and functions have been realized in a prototype system, in which both functions in server and in client (mini-courseware player) have been implemented. Further work include examination validity of the design approach and a special curriculum (Java Program) will be selected and validated, at the same time, more learning resource format (audio, video) supported in ULO will be integrated in server, while some more functions, such as recording status for playing, and replaying etc, will be realized into the mini-courseware player.
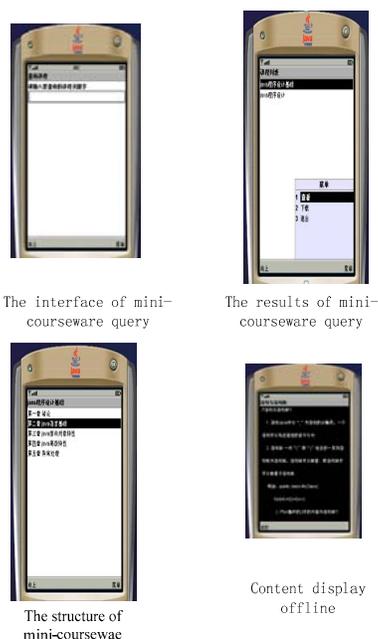

The interface of mini-courseware query

The results of mini-courseware query

The structure of mini-coursewae

Content display offline

Figure 6. The demo of mini-courseware player functions.

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